Mind the Gap between Sustainable Design and Facilities Management

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ABSTRACT: The need for the built environment to improve its energy efficiency is well established. Operating energy is the largest energy consumption component during the life of a building. Decisions taken at the design phase of the building are crucial towards influencing the overall energy demand of a building. There is strong evidence suggesting a gap between the expected and achieved energy performance in non-residential buildings. The lack of understanding regarding how design intent translates into actual performance is one of the main barriers affecting the delivery of high performance buildings. This conceptual paper briefly discusses the reliability gap in the context of the disjointed nature of the construction industry, and contributes to the development of a foundation for the newly launched Norwegian research project “Methodologies for Improvement of Non-residential Buildings' Daily Energy Efficiency Reliability” (MINDER), which aims to narrow the gap by linking the actors and technologies found at both ends of the gap.

The call for world governments to adopt energy savings as their energy resource of first choice has been made (Expert Group on Energy Efficiency 2007). The European Union, through the Energy Efficiency Directive, has set itself a target of achieving 20% energy efficiency improvement by the year 2020. In most developed nations, nearly 40% of all energy consumed is accredited to the built environment; therefore, the building sector has a great potential in contributing to meeting EU energy efficiency goals (Kyrö et al. 2012). For local governments, this has meant framing their energy policies to support alignment of the built environment with wider international initiatives. As a direct consequence, and the need for organizations to remain competitive in a market increasingly driven by sustainability standards, business owners are finding it critical to embed energy efficiency into daily operations (Elmualim et al. 2010).

The decisions taken at the design phase of a building can have strong influence over its energy performance; thence, new buildings offer a unique opportunity for the delivery of integral energy saving solutions (Bragança et al. 2014). Nevertheless, it is well established that the largest energy saving potential lies with the existing building stock (BPIE 2010, Junghans 2012a). Therefore, the value of energy efficiency measures that can be adapted or retrofitted into existing buildings is acknowledged (Ma et al. 2012, Aste & Del Pero 2013). Furthermore, operating energy has been identified as the largest component of energy demand in the lifecycle of a building (Sartori et al. 2009). In this context, building management practices have been regarded as vital to reducing the energy used in a building during its operational phase (Kyrö et al. 2012, Mokhtar et al. 2014)

However, many studies indicate that very often buildings perform much worse than their design intentions (Bordass et al. 2004, Turner & Frankel 2008, Menezes et al. 2012). The bridge between a building’s expected energy demand and its actual performance is commonly referred by practitioners as the energy reliability gap. As suggested by Bordass et al. (2004), the problem is further exacerbated if the reliability gap turns into a credibility gap, thus putting at risk the wider ambitions to realize high-performance buildings. Many factors leading to this energy gap have been identified, including: wrong modelling, poor commissioning routines, poor management of the building and deviation from intended use of facilities. Nevertheless, a review of the literature shows that most of the studies addressing the reliability gap have focused on the technical side of the problem. Moreover, only recently have studies begun to address the complex interactions between architecture and technology, and the people who use and maintain them.

The value in strengthening the level of collaboration between the many stakeholders in the life of a building, particularly those involved during the design and the operation phase, is increasingly gaining attention. In this context, the Norwegian research project "Methodologies for Improvement of Non-residential Buildings' Daily Energy Efficiency Reliability" (MINDER) sets out to accomplish the following: 1) To map the state of the art of the implementation of methods that seek to narrow the reliability gap in Norwegian non-residential buildings and form a design meets operation standpoint; 2) to analyze in depth potentials for improvement and further diffusion, and; 3) based on this and approaches from product design and social science, to propose new modifications and extensions that go beyond the state of the art (Berker et al. 2014).

This paper is structured into four main sections and provides: First, a brief description of the energy reliability gap and an outline of some of the key factors that influence it; second, an outline of the philosophy underpinning the development of the most common approaches to tacking the reliability gap; third, a brief discussion on the literature addressing the disassociation between design and operation in the construction industry and; finally, an insight into how the gap between design and operation is being dealt with from a bottom-up approach.

1 UNDERSTANDING THE RELIABILITY GAP

1.1 *What is the reliability gap?*

In general terms, energy efficiency in the built environment is determined by two factors: First, the rate at which energy is lost through the physical structure of the building, and; second, the rate at which energy is used to meet the energy needs and physical comfort of the occupants (Meir et al. 2002).

In this context, the energy performance of a building can be described as the effectiveness of the building as a system in meeting the abovementioned objectives. The reliability gap, also referred to as performance gap (Trust 2011, HUB 2013), refers to the difference between the energy performance of the building according to design calculations, and its performance as measured during its day-to-day operation.

1.2 *What factors influence the gap?*

The concept of the reliability gap in non-residential buildings is a complicated one in its own right. Firstly, it must deal with the ample characterization of the building-stock, where aspects such as the number of occupants, construction techniques and typical energy demand associated with end-use may vary significantly from one building type to another (Economidou 2011, Junghans 2012b). In addition, many non-residential buildings are also used as public buildings, meaning that energy saving designs must keep faithful to their intended energy performance while adapting to changing user's activities. (Junghans 2012a)

Secondly, the performance gap covers a wide range of complexities, ranging from the design process and energy prediction techniques to the building assessment process including measurement methodologies. For example, the design process encompasses issues covered in the programming phase of the building, where key aspects that influence its energy performance must undergo wide stakeholder agreement.

However, as suggested by Jensen (2009), it is up to the building client to take a leading role in defining the working framework that will support full integration between design and operation; furthermore, financial hurdles such as split incentives and leverage barriers will often keep building owners from making the investments required for adequate energy efficiency operation (Martin & Gossett 2012, Bordass & Leaman 2013). As a result, the view of those who hold strategic knowledge regarding in-use building performance is often neglected.

De Wilde (2014) provides a comprehensive coverage of the root causes that may lead to a performance gap. These include, but are not limited to, changes in the use of the building, system over-specification, problems with particular technologies and even dependencies of new systems on regular software updates.

In view of the challenges at hand, the European Union introduced in 2002 a foundation stone for energy in buildings regulation known as the Energy Performance Buildings Directive (EPBD). The main objective of the EPBD is to improve the built environment by achieving energy efficiency and carbon reduction goals. Effective implementation of the EPBD is supported by the European Commission through the Concerted Action (CA) EPBD, an initiative that supports the gathering and dissemination of best-practice across 29 EU countries, regarding their experience in the adoption of EPBD legislation at a national level (CA Energy Performance of Buildings).

The EPBD is widely acknowledged as a vital framework to narrowing the reliability gap (Bordass et al. 2004); however, inconsistencies such as the mismatch between the standards specified for buildings through the Energy Performance Certificate (EPC), and succeeding operational performance as measured by the Display Energy Certificate (DEC), may further exacerbate the perceived energy performance gap (De Wilde 2014)

Many barriers to implementing energy efficiency measures (EEMs) in non-residential buildings have been identified, and although some studies differ on their hierarchy, most agree that technical issues, financial constraints and lack of knowledge are some of the main aspects hindering wide uptake (Chai & Yeo 2012, Martin & Gossett 2012). Because of these special characteristics, and despite the heterogeneity within this building type, non-residential buildings are much more likely than residential buildings to being designed, managed and operated by professionals who are able to act according to sustainable concepts, methods or employ targeted measures.

The following section outlines the philosophy underpinning the development of the most common approaches to tacking the reliability gap, and provides a brief critique to single-phase technology-specific approaches.

2 ROOT-BASED APPROACHES TO TACKLING THE RELIABILITY GAP

2.1 *The need for balance between technology and management*

One of the first steps in addressing the reliability gap has been to classify the factors that influence it. This was achieved according to the lifecycle phase of the building within which these factors originate.

For instance, Bordass et al. (2004) categorizes some of the key issues affecting energy performance within four key areas, including: design estimations, design development, construction and commissioning, and building management and occupancy. This root-based approach enables, among other aspects, to identify the stakeholders involved in the delivery of the practice, and in turn, those who possess the knowledge and expertise to correct the problem.

In fact, as indicated by De Wilde (2014), most approaches for tackling the energy gap have stemmed from and developed according to a set of pre-defined root causes. Many success stories of these approaches can be appreciated in the literature, including: the state of the art energy prediction systems (Karatasou et al. 2006, Bektas Ekici & Aksoy 2011), methods that aim to support the design and implementation of retrofit technologies (Aste & Del Pero 2013), innovative approaches to fault detection and diagnostics (Du et al. 2014), and a wide variety of tools for assessing building performance (Crawley et al. 2008).

However, many of the available solutions seem to rely on techonological aspects and neglect to address the actual management of these technologies and its associated impact to energy performance.

Trianni (2014) developed a comprehensive framework for the characterization of energy efficiency practices. In its study, a list of 88 Energy efficiency measures were classified according to a series of parameters, ranging from economic aspects, to environmental issues and to concerns relating to implementation procedures. Concerning the later, the study assessed the level of involvement required from corporate personnel towards the management of each technology. Each practice was ranked either as requiring low or wide level of user involvement. The results showed that nearly 80% of all the practices required a low level of involvement from corporate personnel, practically limited to maintenance or repair actions. These results are congruent with the success that "fit and forget" approaches have experienced among industry practitioners, in terms of the ease of management with which these are reasonably associated.

Clearly it is not the aim of this paper to argue against the development of methods that focus on the development of technological solutions to narrowing the reliability gap; however, it is the author's view that in addressing the performance gap, issues regarding the management and use of these methods are given at least a matching significance.

Drawing from system model theory, Ruth & Hannon (2012) suggest that system boundaries are meant to demarcate what we consider essential from that which we judge as unimportant. Common-day practice to tackling the reliability gap has effectively addressed the boundary of space. The advancement of knowledge regarding how a building may perform under a delineated set of known variables is remarkable. However, when considering the boundary of time, building designers often neglect the impact of user-behavior on energy consumption (Gram-hanssen 2013). As suggested by Ruth & Hannon (2012), what tomorrow may be regarded as important, may just not be thought of as important today. The conditions affecting building use inevitably vary over time, whereas that may relate to outdoor climate, changes to design specifications, and even intended use of the facility.

Therefore, it becomes of upmost value to acknowledge the impact of the actual operation of the building when adopting a lifecycle perspective to tackle the reliability gap. Objectively, this means that regardless of the root of the problem, every alternative must: a) Consider its influence over the actors that will become part of the system over the life of the building, particularly those who will use and maintain it, and: b) Acknowledge the input from these actors as of strategic value to the design of each practice.

The previous opens the gate for discussing the development of practices that aim to tackle the reliability gap by linking the actors and technologies found at both sides of the gap, namely design and operation. Easier said than done, the next section will address in more detail challenges underpinning these approaches, and briefly discuss the value of such methodologies from a knowledge management perspective.

3 THE DISASSOCIATION BETWEEN DESIGN AND OPERATION

The value of linking design and operation can be vastly appreciated from the standpoint of knowledge management theory (Love et al. 2011, Kivits & Furneaux 2013, Kim 2014). Knowledge management approaches show that organizational objectives (e.g. improved performance and innovation) can be more effectively achieved when based upon processes that carefully address the gathering, use and sharing of organizational knowledge (Dörr et al. 2013).

As suggested by Way (2005), the fastest approach to elevating the environmental and economic performance of buildings is through learning how buildings operate and provide feedback to future projects. This is to say, to develop collaborative networks between the people who design buildings and those who operate it. Furthermore, several recent studies are highlighting the importance of addressing the complex interactions between a person and the building it occupies, and the impact of these relationships on the overall energy performance of the building (Mohareb et al. 2011, Azar & Menassa 2012, Kyrö et al. 2012, Gram-hanssen 2013, Mokhtar et al. 2014). Thence, the experience gathered by the building operator regarding the behavior of its occupiers, becomes an important knowledge-pool of practical experience. Boyd (2013) defines this type of information as event-based knowledge, and advocates for it to become the basis for collecting, structuring and sharing lessons in the construction industry.

The value of supporting knowledge flow between design and operation towards improving the energy performance of the building stock (old and new) is well acknowledged; however, little effort has been paid to achieve this (Wang et al. 2013). In the context of the construction industry, it is somewhat useless to discuss the benefits of methods based on stakeholder collaboration, without addressing the challenges rooted to its disjointed nature (Elmualim et al. 2012). Particularly, the fragmentation between design and operation can be explained as a by-product of both industry characterization and professional competence.

The first layer of segmentation is an expression of the singularities of the construction industry. Fulford (2014) conducted an extensive review of the literature to identify the factors inhibiting collaboration in the construction industry, and applied this knowledge towards the development of collaborative networks within the Australian construction industry. Drawing from this study, the construction sector can be broadly described as a low-cost service driven market, strongly represented by a high number of small and medium enterprises (SMEs) that compete against one another over a sequence of one-off kind projects. As suggested by Fulford (2014), collaboration in the sector is often characterized by project specific ventures; however, even then organizations often fail to seize the benefits of collaboration because they lack the funds to invest in the necessary IT infrastructure. In this context, building contractors and building operators can be thought of as incompatible small operating units, forced to sacrifice the creation of value through collaboration over the opportunity to offer a low-cost service.

Another aspect which seems to hinder further integration between design and operation is the issue of the current development of the facilities management profession. Facilities operators are increasingly being seen to play an important role in the design and delivery of high performance buildings; however, the profession is often seen to lack the necessary knowledge to engage as equal in the design process dialogue (Bordass & Leaman 2013; Jensen 2009, Preiser & Vischer 2005).

In spite of the evident difficulties underpinning the energy reliability gap from a design-operation standpoint, industry experts have already taken the lead in the development of practical solutions aimed at reducing the gap. The following section provides an overview of the state of the art on these practices. The selection criteria are briefly outlined at the beginning of the section.

4 BOTTOM-UP APPROACH TO NARROWING THE RELIABILITY GAP

This section draws from the state of the art regarding practices tackling the reliability gap. Only methods which have a direct or indirect impact on strengthening the link between design and operation are covered. The aim is not to provide an exhaustive account of all approaches that fit these criteria, but to give an overview of the methodologies that are currently finding their way in industry across the European Union.

Based on the author’s perception, these methods are presented according to their level of complexity, thus allowing for the gradual integration of new elements into the discussion.

4.1 *Soft Landings (SL): A process carrier framework*

This method aims to improve the overall performance of a building by maximizing the knowledge flow between the client and the building contractors. The previous is achieved mainly by extending, through contractual agreement, the involvement of the design and construction team beyond the defect liability period (Way 2005). The objective of this method is to ensure that all important decisions regarding the structure and performance of the building consider the views from all relevant stakeholders (Way 2005).

From the perspective of sustainable design, a solid opportunity is created for building contractors to learn how design translates into actual performance. In turn, this knowledge can be used to develop new buildings that demonstrate improved energy performance. On the other hand, facility operators are able to learn from the building contractors how the building is meant to be operated and maintained. In addition, the building operators will be in a position to guide the development of post-handover training programs (BSRIA 2014).

From a theoretical standpoint, the prospect for transferring lessons learnt into new projects is clear; however, further research is necessary to understand how this opportunity can, in practice, be seized by industry to further develop the sustainable design process.

4.2 *Continuous Commissioning (CCx): Integrating actors through technology*

In stark contrast to the project management approach adopted by Soft Landings, CCx establishes a technological link between building designers and operators. This method parts from the principle that factors such as building use and occupancy will vary over time; therefore, the systems that control the building's performance should be continuously adjusted to ensure its optimal performance (Liu et al. 2002).

This method requires for organizations to invest in different types of energy management technology, such as fault detection and diagnostic mechanisms (FDD), an energy management system (EMS), as well as other relevant tools that enable the system manager to intervene and adjust the building's operating systems in a timely manner (Nord et al. 2012). Due to the technical characterization of this method, effective operation requires specialized knowledge; thus, the system operator should be a well-trained professional, preferably from an engineering background (Liu et al. 2002, Nord et al. 2012). Far from downgrading the role of in-house facility operators, Liu et al. (2002) sees this as an opportunity to raise their competences, as ideally they will be working closely with the CCx system manager in defining and implementing the necessary commissioning measures.

There is vast opportunity to use the data that is collected through the energy management system to inform the design process of new buildings; however, as suggested by (Bordass et al. 2001), the challenge lies in the capacity to process this data, translate it into usable information and disseminate it to a wider audience. On the other hand, the operating framework does not seem to suggest an intention to support the development of the design process; instead, it seems to be satisfied with the notion that a building's energy performance can be stabilized and even improved, on a project by project basis, through the responsible use of a sound technological energy management platform.

4.3 *Energy Performance Contracts (EPC): A business model approach to narrowing the energy gap*

Energy Performance Contracts (EPC) are turnkey agreements where clients are offered an array of services ranging from energy efficiency, renewable energy and distributed generation, often with the guarantee that the cost of the project will be absorbed by the project savings alone ("EC Energy Performance Contracting"). The company offering the EPC service, commonly known as Energy Service Companies (ESCo), may be contracted to deliver useful energy (e.g. heating, cooling), provide a specific "function" (e.g. temperature, lighting level), or to integrate measures that cover both the supply and demand side of energy efficiency measures (Wargert 2011).

Due to the wide spectrum of services that may be offered by an ESCo (e.g. energy audit, commissioning and operations & maintenance) (IFC International and National Association of Enegy Services Companies 2007), it could be argued that involvement from in-house building operators is mostly limited to providing support regarding the coordination of activities. In addition, it could be reasoned that because EPCs stem from a profit driven business model, it is counter-intuitive to expect that the ESCOs would be interested in sharing their know-how with building contractors and operators. However, an EPC may result in raising the profile of the facilities operators through the training provided as part of the contract agreement ("EEC Energy Performance Contracting").

4.4 *Building Performance Evaluation (BPE): Increased performance through quality assurance*

Building Performance Evaluation (BPE) is described by Preiser & Vischer (2005) as "the process of systematically comparing the actual performance of buildings, places and systems to explicitly documented criteria for their expected performance." BPE stems from Post-Occupancy Evaluation (POE) where building occupants are the focus of attention. The method is based on a principle of continuous feedback throughout the life of a building; therefore, it provides a good opportunity for knowledge-building in the design and construction industry (Bordass & Leaman 2005).

Input from facility operators and building occupants is regarded as of strategic value to improving the building's potential performance, and work together with designers to decide on form (Preiser & Vischer 2005). In this context, BPE is more effective when implemented through Soft Landings (SL).

In brief, BPE provides a comprehensive framework that supports wide stakeholder engagement and, from a theoretical standpoint, facilitates the integration of both management and technological approaches to bridging the gap between design and operation.

5 BRIDGING THE GAP: MOVING FORWARD

Clearly, there are many other promising methods that are worth discussing; for example, Continuous Briefing (Jensen 2006), Building Information Modelling (Wang et al. 2013) and Value Management & Engineering (Green 1994). The main reason why these practices are not particularly addressed is that their underpinning philosophy, i.e. either soft or hard systems thinking, is at least partially accounted for within the methods that were previously described.

Of particular interest to the newly launched research project MINDER is the integration of principles from social practice theory and design thinking, in the assumption that these are able to complement the abovementioned practices. The underlying principle is that the reliability gap can be partly explained by the modifications that take place in a building, when the building occupants make use of the facilities within a particular social context (Berker et al. 2014).

This multi-disciplinary project will encompass a multi-method approach to research and include: a self-administered survey, followed up by case studies and an in-depth analysis influenced by both design thinking and social practice theory as theoretical background (Berker et al. 2014).

6 CONCLUSION

This paper has described the reliability gap in non-residential buildings and briefly discussed the factors that influence it. Increased collaboration between building contractors and facility operators is seen as a strategic objective towards improving the delivery of energy efficient buildings; however, current efforts are affected by the barriers associated to the fragmented nature of the construction industry, as well as to the current level of development of the facilities management profession.

Current methods aimed at tackling the gap seem to suggest three key aspects: First, that collaboration in a disjointed industry needs to be enforced through contractual liability; second, that hardcore technological approaches to improving building performance offer the clearest decision-making platform for building owners to invest in energy efficiency measures, and; third, that regardless of knowledge management being perceived as a critical component of some these methods, it remains unclear how individual contractors and demand organizations (i.e. design, construction and client) will learn from their experiences, and adjust their operating framework accordingly.

In addition, the growth of technological approaches to energy management means that the potential to learn about how building occupants influence energy consumption is vast; however, in order to seize this opportunity, the industry would benefit from the participation of disciplines that place the user-behavior at the center of a building's energy demand.

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